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The mangosteen flowering date model in Nakhon Si Thammarat province, southern Thailand

Poontarasa OUNLERT[1], Sayan SDOODEE[2*] and Pitsanu TONGKHOW[3]

[1]Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Songkhla, Thailand.

[2*]Department of Plant Science, Faculty on Natural Resources, Prince of Songkla University, Hat Yai, Songkhla, Thailand [*]correspondence: sayan.s@psu.ac.th

[3]Department of Industrial Engineering, Faculty of Engineering, Rajamangala University of Technology Phra Na Khon, Bangkok, Thailand

Abstract

Mangosteen (*Garcinia mangostana* L.) is one of the economically important fruits of Thailand. Recent studies show that the climatic variability affects the flowering period of tropical fruit trees. The objectives of this study are: 1) to investigate the correlation between climatic factors (in particular with, rainfall, maximum temperature, minimum temperature, relative humidity, and dry period before flowering) and mangosteen flowering date and 2) to develop the poisson regression model to predict the flowering date of mangosteen in Nakhon Si Thammarat Province, Thailand. This model is useful in guiding farmers to manage mangosteen orchards. The results showed that the rainfall, the maximum and minimum temperatures, the relative humidity, and the dry period before flowering dates affect mangosteen flowering dates. The model which will be used as a guideline for mangosteen flowering date prediction was $\log(\mu)=10.85+0.0001x_1-0.0564x_2-0.0634x_3-0.0232x_4+0.0003x_5$ where μ is the mean of mangosteen flowering date, x_1 is rainfall, x_2 is maximum temperature, x_3 is minimum temperature, x_4 is relative humidity, and x_5 is dry period before flowering date.

Keywords: climatic factors, flowering date, mangosteen, model, poisson regression

Introduction

Mangosteen is one of the economically important fruits of Thailand. The exportation value of mangosteen increased steadily during 2010-2014 and the revenue from mangosteen exporting was 55.88, 59.16, 83.41, 122.76, and 138.15 million respectively USD (Office of Agricultural Economics, 2015). Mangosteen is the tropical fruit that requires a drying period before flowering (Chutinunthakun, 2001; Sdoodee and Chiarawipa, 2005; Apiratikorn et al., 2012) and the mangosteen flowering period is induced by a short dry period of 15-30 days (Yaacob and Tindall, 1995). Normally, southern region of Thailand is suitable for growing tropical fruits because of humid tropical climate. Nonetheless, recent studies show that the climatic variability affects the flowering period of longkong (*Lansium domesticum* Corr.) and mangosteen in Songkhla, Phattalung and Nakhon Si Thammarat Provinces (Uraipan, 2009; Apiratikorn et al., 2012; Apiratikorn et al., 2014; Ounlert and Sdoodee, 2015). The delayed mangosteen flowering dates may be due to an impact of unproper orchard management. If the flowering of mangosteen delays to a heavy rain period, a harvesting period may occur during the rainy season in which excess moisture could damage mangosteen fruits.

It is argued that if the farmers can predict the mangosteen flowering dates, they will be able to effectively manage the harvesting period. Many models have been developed to predict the flowering date, full bloom, and first harvest using phenological data reported in cherry, peach, pair, blueberry (Schwartz et al., 1997; Muñoz et al., 2012; Allen et al., 2014; Hur and Ahn, 2015). Partial least-square regression was employed to develop a prediction model (e.g. Aguilera et al., 2015). However, in mangosteen, dependent variables (climatic factors) are poisson distribution. Thus, it is suggested that the poisson regression is suitable to use in developing the model to predict the flowering period of mangosteen. The poisson regression model is similar to the regular multiple regression except that the dependent (y) variable is an observed count that follows the poisson distributions. Therefore, the objectives of this study are 1) to investigate the correlation between climatic factors (rainfall, maximum temperature, minimum temperature, relative humidity, and dry period before flowering) and mangosteen flowering date in Nakhon Si Thammarat Province and 2) to develop the poisson regression model to predict the flowering date of mangosteen in Nakhon Si Thammarat Province, Thailand.

Materials and methods

Data: In mangosteen, there is only one cultivar because mangosteen is apomixis fruit trees that female trees produce fruit without pollination. Mangosteen cultivating areas investigated in this study are in many districts of Nakhon Si Thammarat Province: Phrom Khiri district (8°31′18″N, 99°49′30″E), Lan Saka district (8°22′18″N, 99°48′18″E), Cha-uat district (7°57′54″N, 99°59′54″E), Thung Song district (8°31′18″N, 99°49′30″E), and Chawang district (8°25′34″N, 99°30′17″E). Data of flowering dates were collected from mangosteen orchards in the aforementioned districts during 2000-2012. The meteorological data were obtained from Nakhon Si Thammarat Meteorological Station, Water Management Center for Southern Region of Phattalung Province where is adjacent to Nakhon Si Thammarat Province, and Nakhon Si Thammarat Rajabhat University Rain Station. The factors related to mangosteen flowering date were rainfall, average maximum and minimum temperature, average relative humidity, and dry period before flowering. Drying period was assessed by the data of evaporation and rainfall.

Models: Poisson regression model and hierarchical Bayesian model are studied to determine the correlation between the climatic factors and the flowering dates of mangosteen. A poisson regression model is expressed as:

$$\log(\mu_t)= \beta_0+\beta_1 x_{1t}+\beta_2 x_{2t}+\beta_3 x_{3t}+\beta_4 x_{4t} +\beta_5 x_{5t} \qquad (1)$$

where, at time t, t = 1, …, n, μ is flowering date, x_{1t} is rainfall, x_{2t} is maximum temperature, x_{3t} is minimum temperature, x_{4t} is relative humidity, x_{5t} is dry period before flowering, β_0, β_1, β_2, β_3, β_4 and β_5 are fixed parameters. The parameters are estimated by the maximum likelihood approach (Tongkhow and Kantanantha, 2011). The hierarchical Bayesian model (Bayes' Theorem) is expressed as:

$$p(\theta|D)= \frac{I(D|\theta)p(\theta)}{p(D)} \qquad (2)$$

The most common statistical inference approach consists in finding the parameter vector θ maximizing the value of the likelihood I(D|θ) using the maximum likelihood approach where I(D|θ) is likelihood, p(θ|D) is posterior distribution which stands for the marginal probability density of the parameter vector θ given the data set D, p(θ) is so-called the prior distribution of θ, which summarizes any a prior or alternative knowledge on the distribution of θ, and p(D) is the probability of the sample D which is unknown (Tongkhow and Kantanantha, 2011). MCMC algorithms combining random walk Monte Carlo methods with Markov Chains are the class of algorithms for sampling from multivariate distribution efficiently. The final result of MCMC is a set of vectors θ with density p(θ|D) in which the model parameters can be estimated. There are three stages of hierarchical Bayesian model. At the first stage, a distribution for the data given parameters is specified. The second stage, prior distributions for parameters given hyper-parameters is specified and distributions for hyper-parameters are specified at the third stage. Complex models can be built through the specification of several simple stages under hierarchical Bayesian framework (Tongkhow and Kantanantha, 2011).

Results

The Gibbs Sampling MCMC was converged when being run for 50,000 iterations and the initial 10,000 iterations were discarded. The history plots of all parameters showed no trend around the mean (Figure 1). In addition, the Kernel density plots of all parameters did not show a multi-modal curve (Figure 2) that mean MCMC converged to some distribution patterns. The summary of estimated parameter was presented in Table 1.

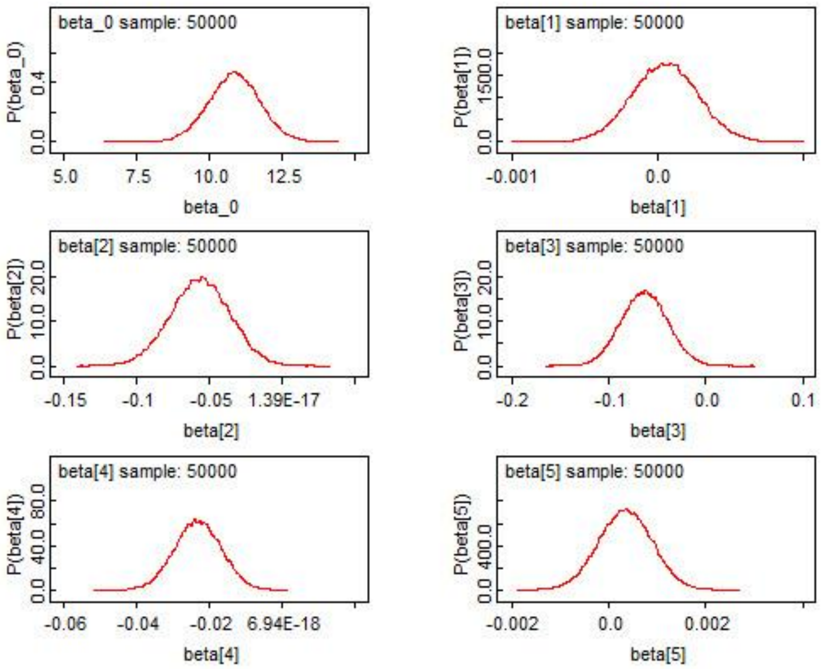

Figure 1. Density plot indicating MCMC convergence of β_0, β_1, β_2, β_3, β_4, and β_5

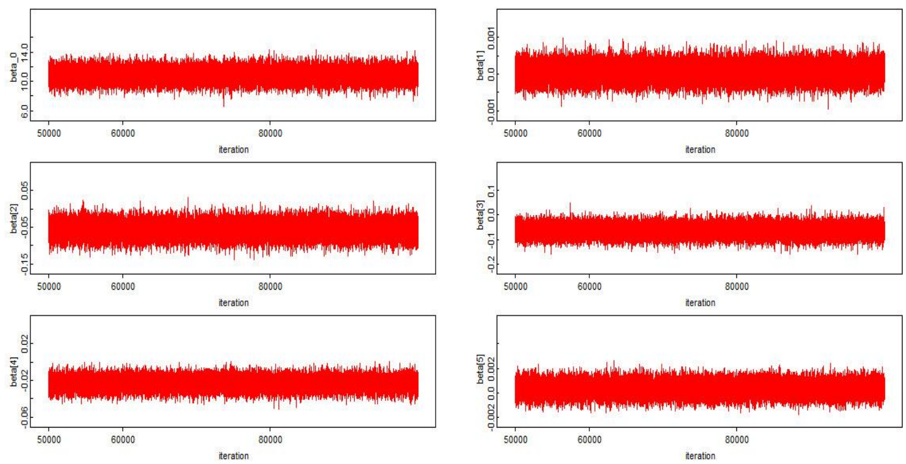

Figure 2. History plots indicating MCMC convergence of 50,000 iterations and the initial 10,000 iterations were discarded

The estimated parameter from the poisson regression model in Table 1 indicates that the rainfall, the maximum and minimum temperatures, the relative humidity, and the dry period before flowering affect mangosteen flowering dates. The result in Table 1 shows that the mean of mangosteen flowering date is 1,0001. In other words, the mean of mangosteen flowering date increased by 0.01% when the amount of rainfall changed by 1 unit, other things else remained constant. If the dry period before flowering date changed by 1 unit (other factors remained unchanged), the mean of mangosteen flowering date was 1.0003 times or the mean of mangosteen flowering date increased by 0.03%. For temperature factor, if the maximum temperature changed by 1 unit (other factors remained unchanged); the mean of mangosteen flowering date was 0.9452. In other words, it decreased by 5.64%. If the minimum temperature changed by 1 unit (other factors were unchanged), the mean of mangosteen flowering date reduced to 0.9386 times or the mean of mangosteen flowering date decreased by 6.34%. And the mean of mangosteen flowering date was 0.9771 times or the mean of mangosteen flowering date decreased by 2.32% when the relative humidity changed by 1 unit, other factors remained unchanged. The poisson regression model shown as following:

$$\log(\mu) = 10.85 + 0.0001x_1 - 0.0564x_2 - 0.0634x_3 - 0.0232x_4 + 0.0003x_5 \quad (3)$$

where μ = the mean of mangosteen flowering date
x_1 = rainfall
x_2 = maximum temperature
x_3 = minimum temperature
x_4 = relative humidity
x_5 = dry period before flowering date

Table 1. The estimated parameters (Rain, Maximum Temperature, Minimum Temperature, Relative Humidity, and Dry period) from poisson regression model

Factors	Mean	Standard deviation	97.5% Credible	exp(Mean)
Rain	0.0001	0.0002	0.0005	1.0001
Maximum Temperature	-0.0564	0.0204	-0.0164	0.9452
Minimum Temperature	-0.0634	0.0238	-0.0167	0.9386
Relative Humidity	-0.0232	0.0064	-0.0108	0.9771
Dry period	0.0003	0.0006	0.0014	1.0003

Discussion

Results showed that the climatic factors—i.e. rainfall, maximum and minimum temperatures, relative humidity, and dry period—before flowering affected mangosteen flowering date in Nakhon Si Thammarat Province. The pattern of rainfall distribution directly affected the mangosteen flowering. The factor which affected the flowering date was the decrease of rainfall before flowering about 1-2 months because the mangosteen dormancy occurred in the dry period in order to assimilate accumulation for flowering and fruiting (Sdoodee et al., 2010). Mangosteen is a tropical fruit that is sensitive to water stress. Many studies showed that water stress tropical fruit trees are normally affected by the water stress before flowering (e.g. carambola (Salakpetch et al., 1990), rambutan (Salakpetch et al., 1992), and mangosteen (Poonnachit et al., 1996)). In addition, Makhonpas and Kunjet (2015) also illustrated that water stress might be induced by waterlogging and above ground covering shealth could induce physiological change. In Indonesia, the mangosteen flowering period occurred between September and October 2009 because of the pattern of rainfall causing the short dry period between July and August 2009

(Setiawan et al., 2012). In later year (2010), the short dry period occurred in April that induced the mangosteen flowering in May (Setiawan et al., 2012).

The temperature is also the main factor causing the impacts on the phenological development of tropical fruit trees. Vorakuldumrongchai et al. (2010) reported that if the temperature decreased steadily for 3-5 days during flowering of durian, this led to flower falling. The flowers naturally do not bloom when the temperature decreases steadily for 1 week to 1 month during flowering. The studies of the effects of climate on floral initiation of mangosteen and rambutan suggested that the minimum temperatures could induce the flowering of mangosteen and rambutan (Manakasem, 1995a; Manakasem, 1995b). The minimum temperature that induced the mangosteen and rambutan flowering is 21ºC and 23ºC, respectively. The increase in minimum temperature by 1ºC could cause the decrease in the flower induction of mangosteen and rambutan by 10.5% and 6.7%, respectively (Manakasem, 1995a; Manakasem, 1995b). Furthermore, the temperature plays an important role in the growth of other fruit trees. The greater number of hours at 11ºC to 15ºC increased flowering buds per shoot of Hamlin and Valencia oranges and high winter temperatures reduced the flowering of both cultivars (Valiente and Albrigo, 2004). In addition, Hariyono et al*.* (2013) reported that there is correlation between the flowering period and the temperature, temperature difference, and minimum temperature in different altitude.

However, the studies of the effects of climatic variability on the flowering indicated that the climate change caused the delay of flowering dates of longkong (Uraipan, 2009; Apiratikorn et al., 2014), and mangosteen (Boonklong et al., 2006; Apiratikorn et al., 2012; Apiratikorn et al., 2014; Ounlert and Sdoodee, 2015). Normally, the mangosteen flowering period of the off-season production in southern Thailand is between June and September (Puttakan, 1993; Manakasem, 1995a; Suamag, 2005). In Nakhon Si Thammarat Province, the average flowering date of mangosteen during the off-season delays by 5.10 days*year^{-1} (Ounlert and Sdoodee, 2015). The mangosteen flowering period tends to shift to heavy rain period. The predicting model in this study showed that climatic factors affected mangosteen flowering date. This model will be helpful for the farmers in the orchard management. However, one caveat of this model is that it is developed based on data collected only in Nakhorn Si Thammarat Province. It is suggested to investigate further including mangosteen orchards in other areas of Thailand.

Conclusion

The climatic factors (specifically, rainfall, maximum and minimum temperatures, relative humidity, and dry period before flowering) impact mangosteen flowering date in Nakhon Si Thammarat Province. The model which will be used as a guideline for mangosteen flowering date prediction was $\log(\mu) = 10.85+0.0001x_1-0.0564x_2-0.0634x_3-0.0232x_4+0.0003x_5$ where μ is the mean of mangosteen flowering date, x_1 is rainfall, x_2 is maximum temperature, x_3 is minimum temperature, x_4 is relative humidity, and x_5 is dry period before flowering date. It is suggested that the poisson regression model is useful to predict the mangosteen flowering date because it incorporates all factors that influence the pattern of the mangosteen flowering date without restrictions. At this stage the model is meant to emphasize the study of mangosteen. Future study will apply this model to study other fruits.

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